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An investigation of Mode I and Mode II fracture toughness enhancement using aligned carbon nanotubes forests at the crack interface

Falzon, B. G., Hawkins, S. C., Huynh, C. P., Radjef, R., & Brown, C. (2013). An investigation of Mode I and Mode II fracture toughness enhancement using aligned carbon nanotubes forests at the crack interface. *Composite Structures*, 106, 65-73. <https://doi.org/10.1016/j.compstruct.2013.05.051>

Published in:
Composite Structures

Document Version:
Early version, also known as pre-print

Queen's University Belfast - Research Portal:
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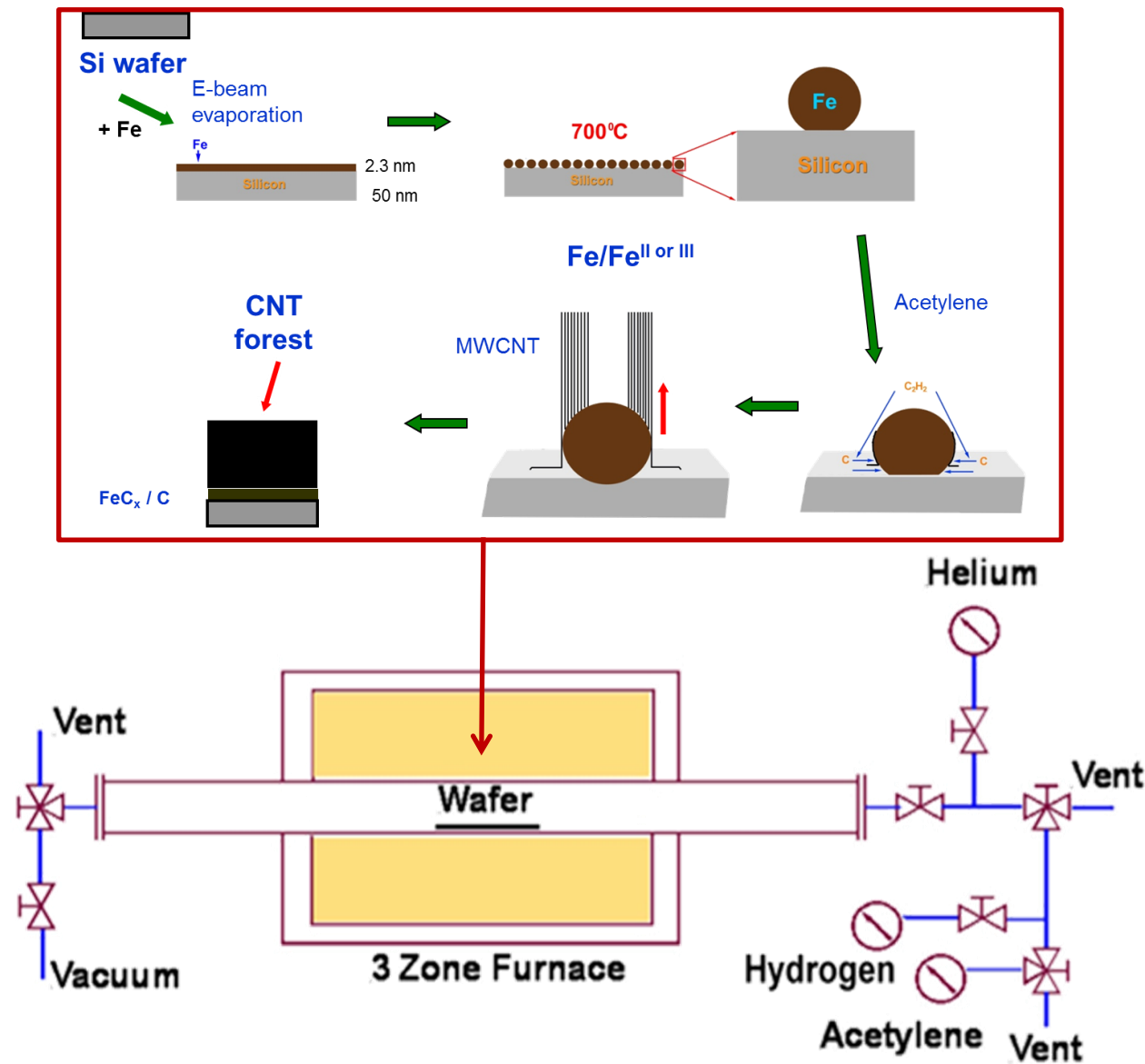
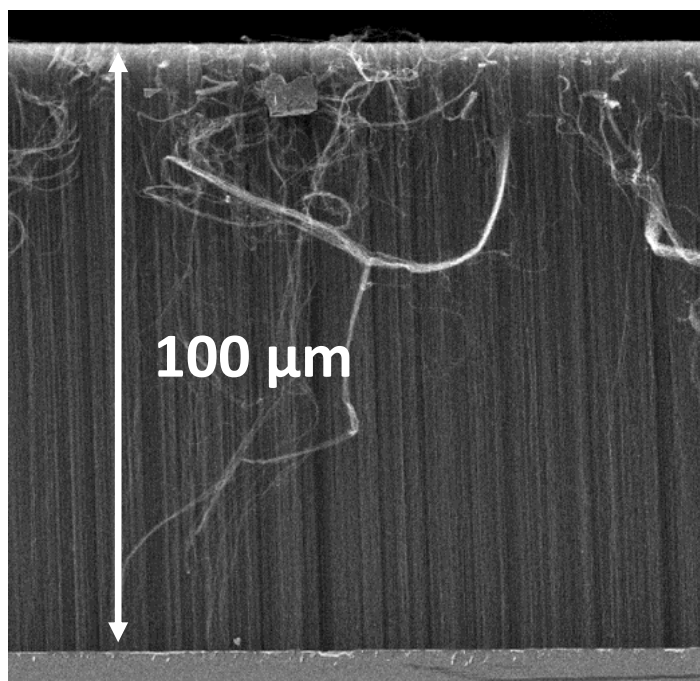
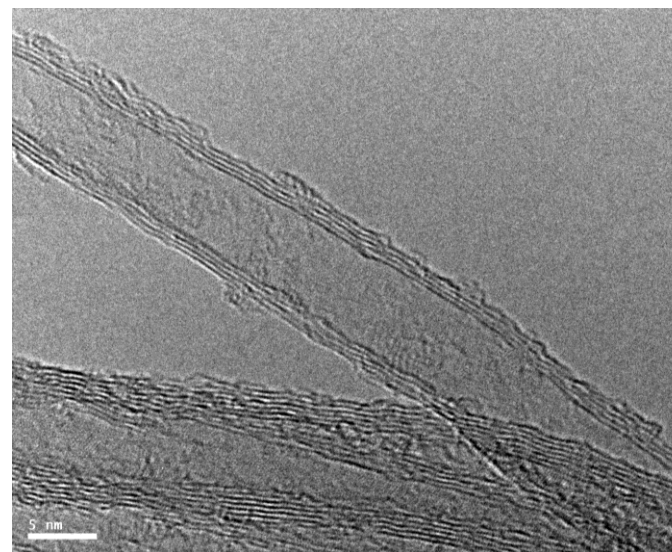


Figure 1: Production of CNT forests.



(a)



(b)

Figure 2: (a) SEM image of CNT forest (b) HRTEM image of MWCNTs.

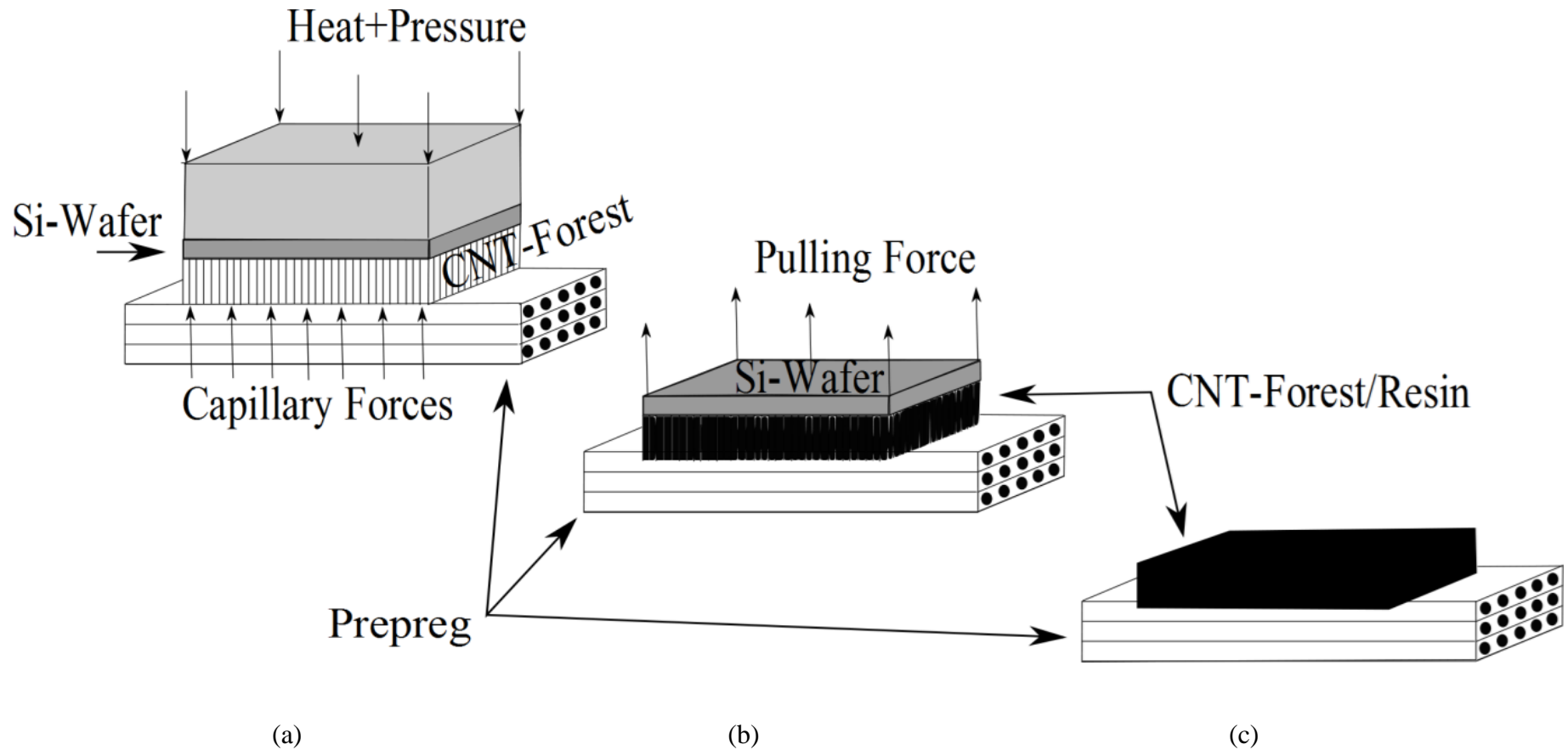


Figure 3: Transplantation of CNT forest (a) heat and pressure applied to silicon substrate (b) removal of the substrate after the cool down period (c) transplanted CNT forest infused with resin through capillary action and partially inserted into the prepreg.

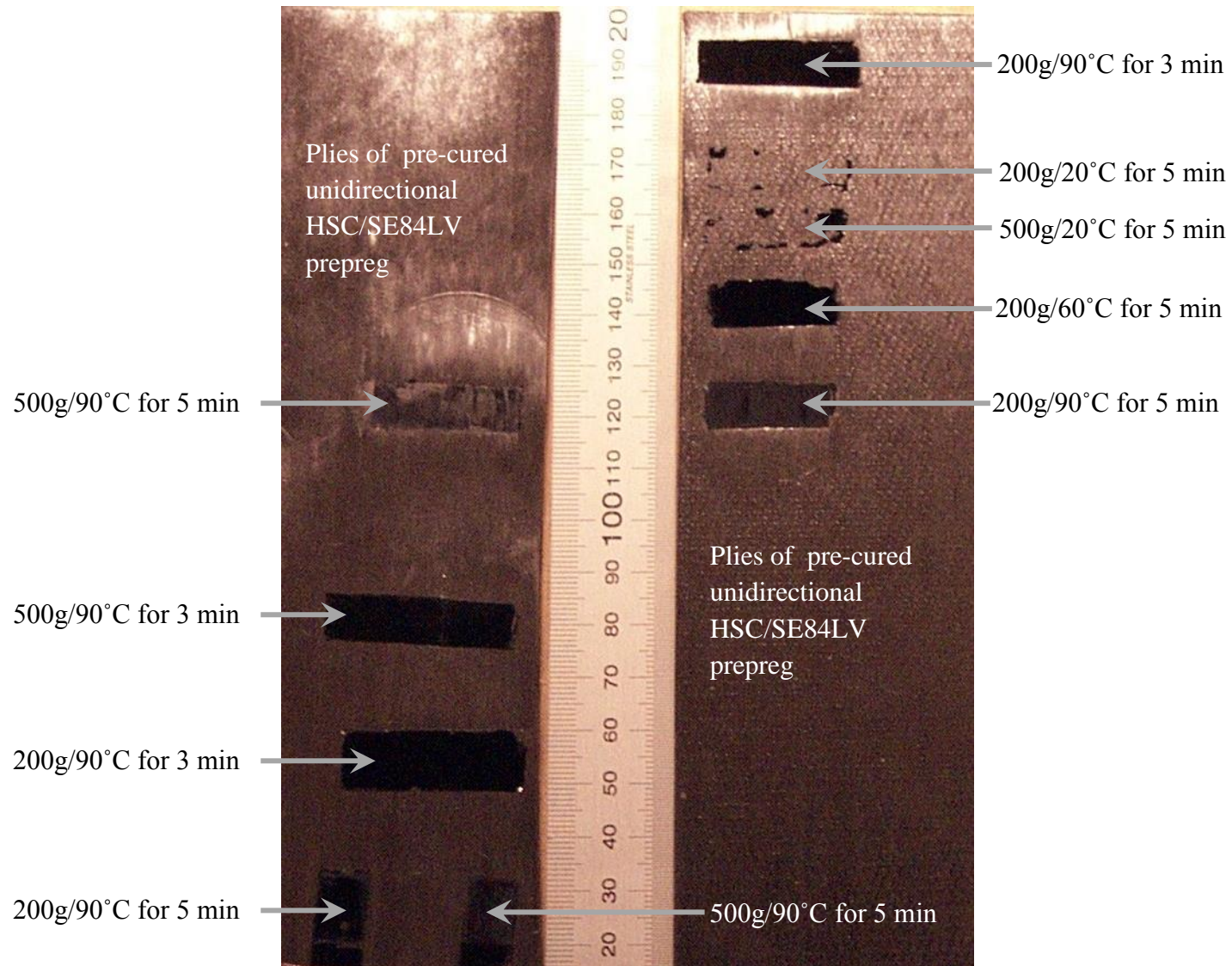


Figure 4: Transplantation tests using combinations of heat and pressure (T700/SE84LV).

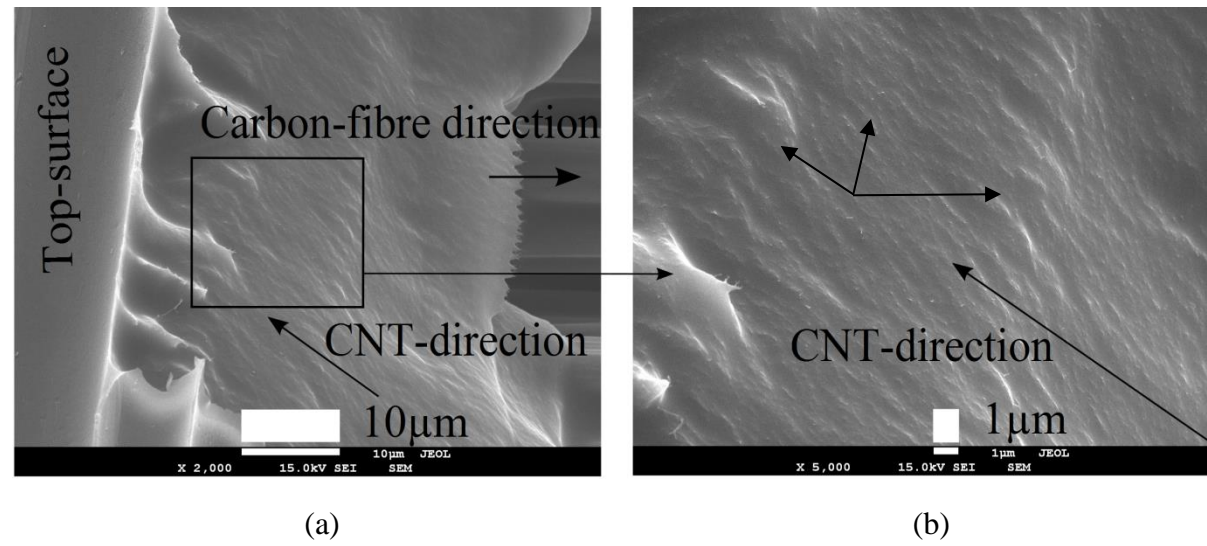
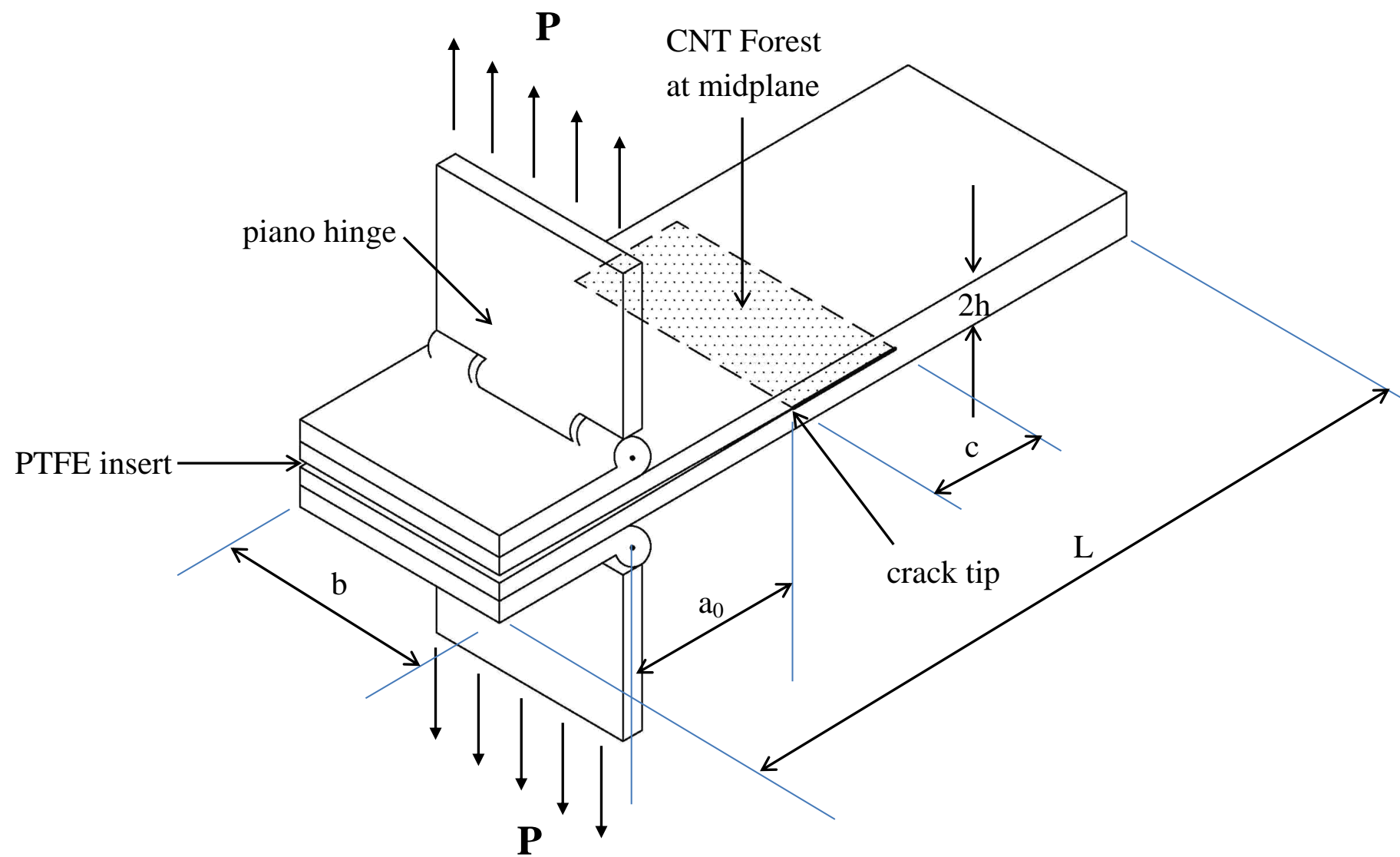


Figure 5: (a) CNT forest (b) detail of CNT forest showing complete wetting.



(a)

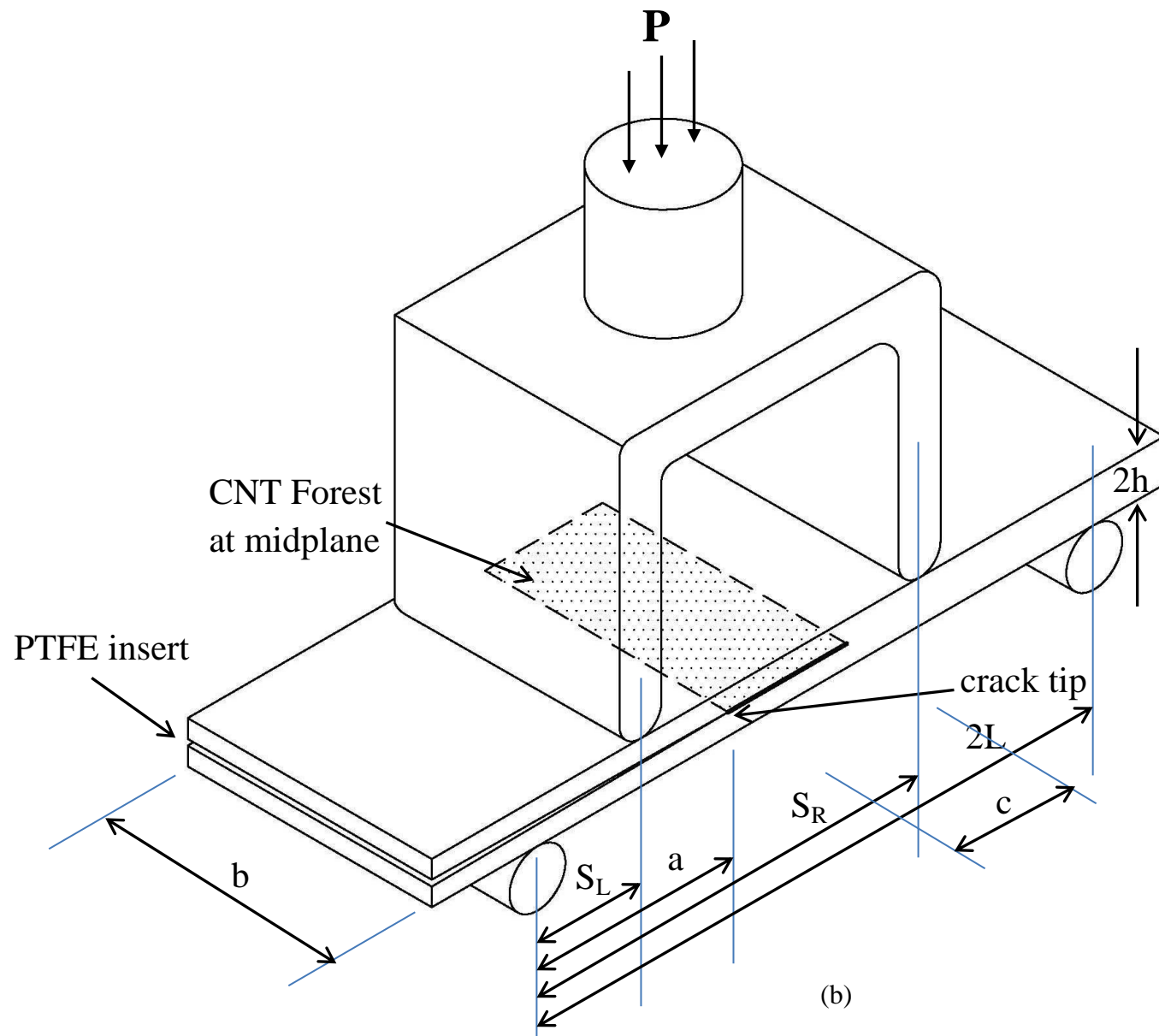


Figure 6: (a) Mode I DCB test (b) Mode II four-point bend test.

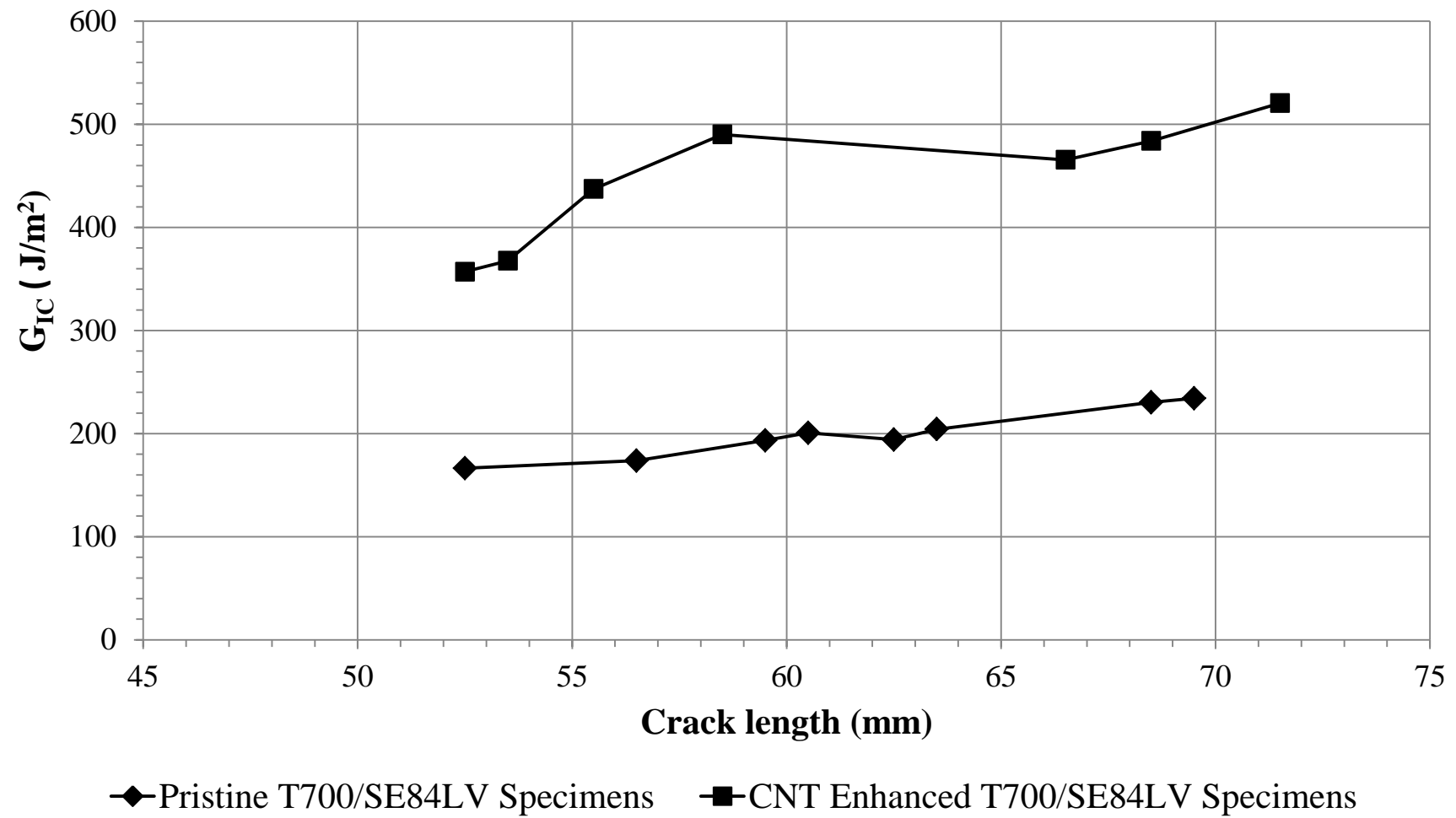


Figure 7: Representative R-curves from GURIT T700/SE84LV Mode I DCB tests.

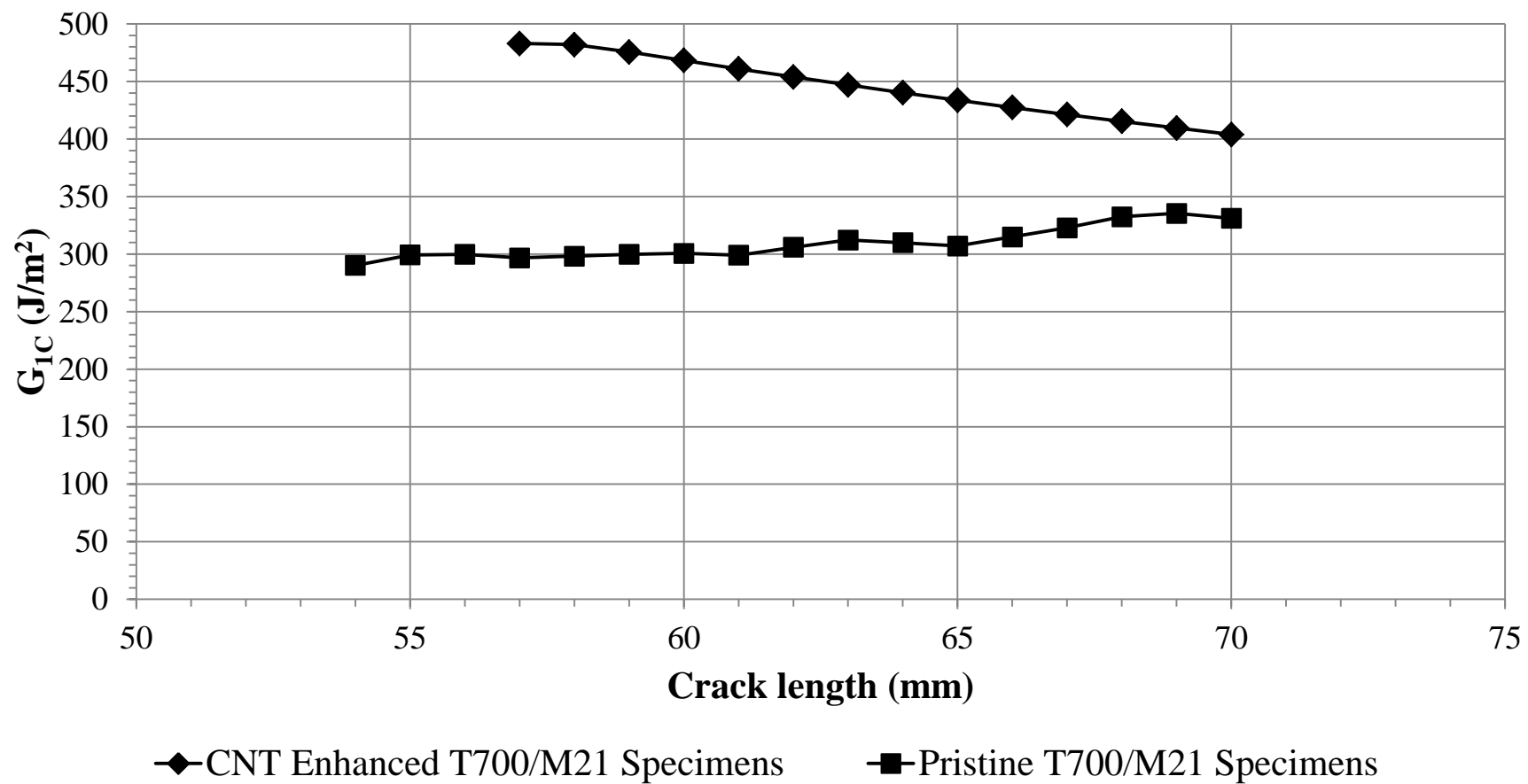


Figure 8: Representative R-curves from HEXCEL T700/M21 Mode I DCB tests.

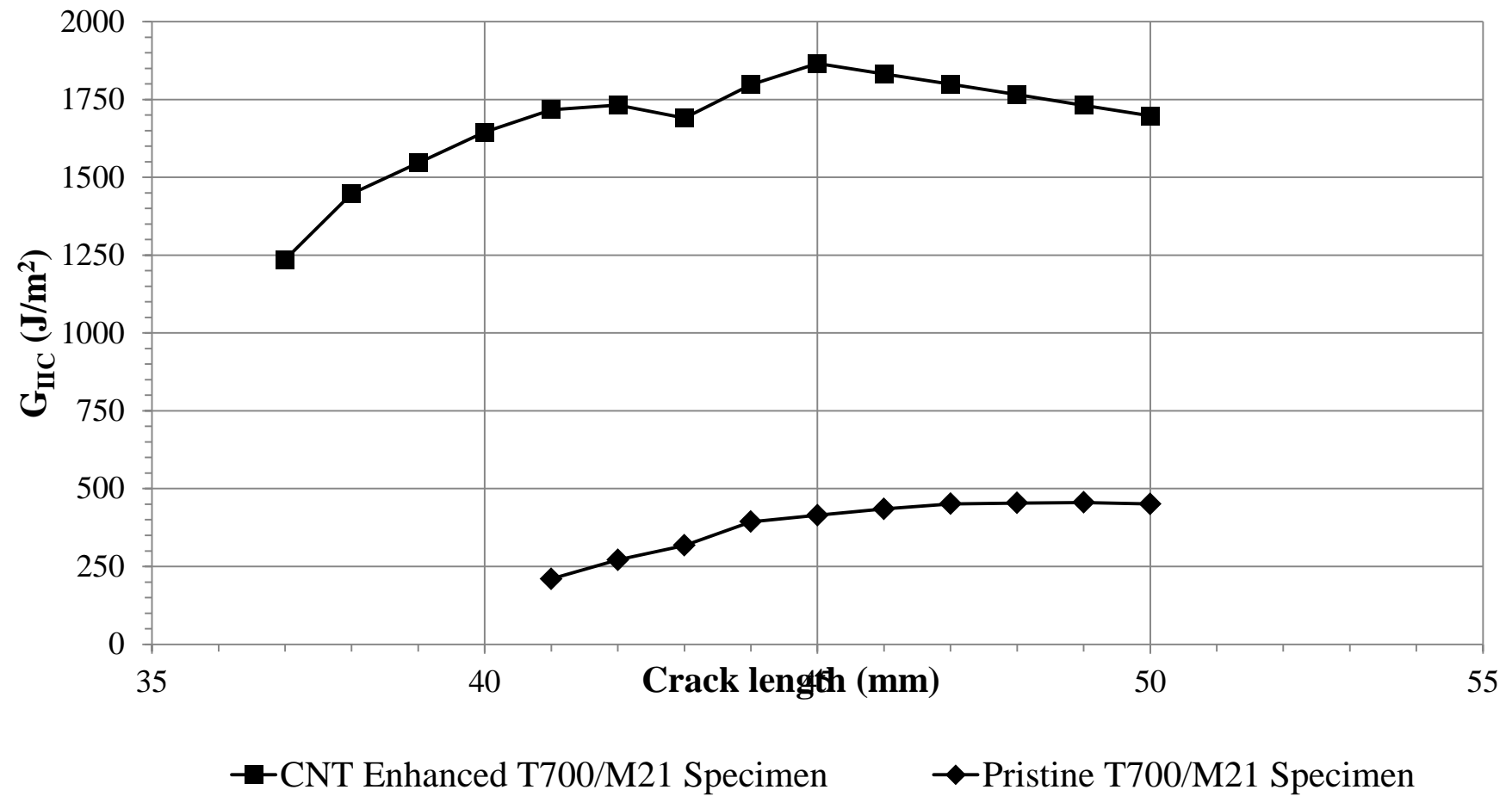
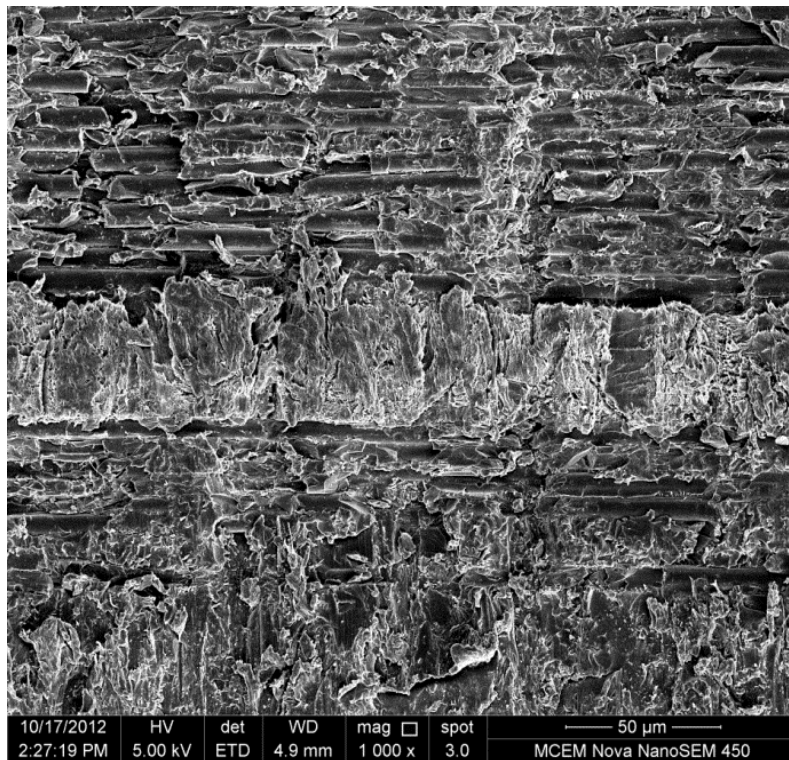


Figure 9: Representative R-curves from HEXCEL T700/M21 Mode II DCB tests.

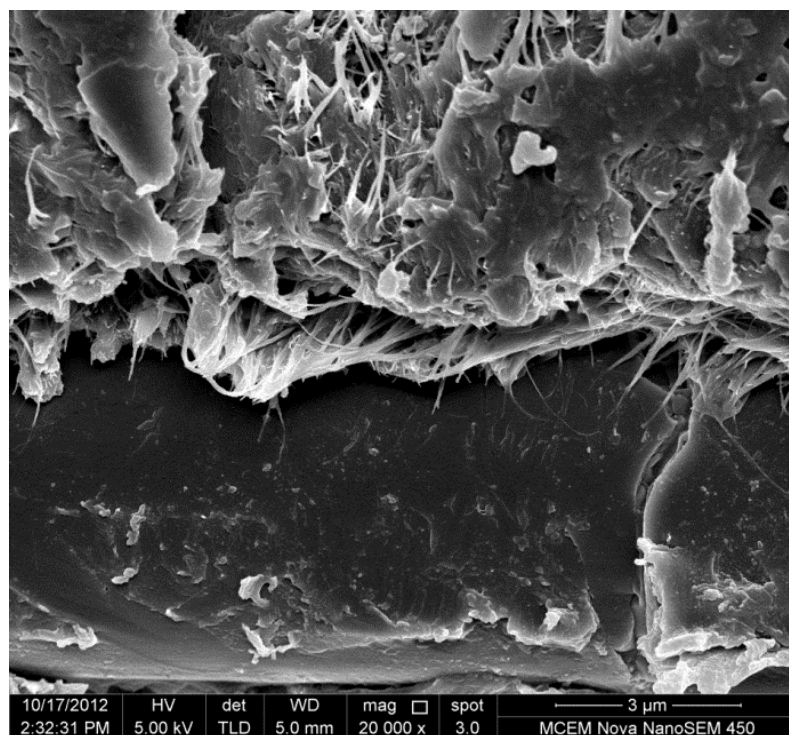


← Composite ply

← CNT enriched interface

← Composite ply

(a)



← CNT enriched interface

← Carbon fibre

(b)

Figure 10: (a) SEM image showing embedded CNT forest (b) CNT forest wrapped around carbon-fibre.

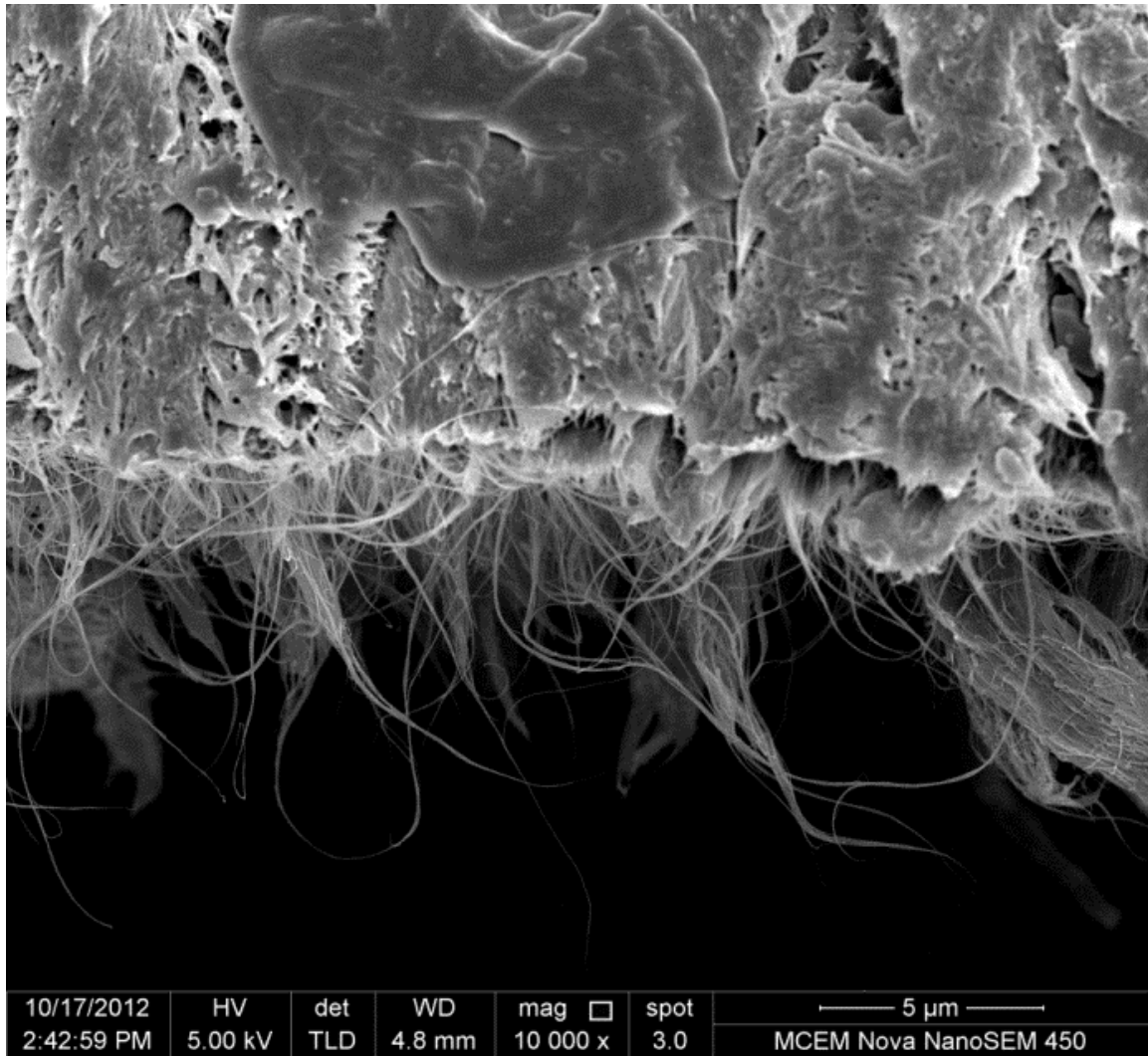


Figure 11: Fracture surface showing ‘sword-in-sheath’ failure mechanism of MWCNTs.

Table 1: Mode I and Mode II fracture toughness values (average \pm one standard deviation)

Specimen material	Fracture mode	Specimen type	Average fracture toughness (J/m^2)	Number of specimens	Average increase in fracture toughness
T700/SE84LV	I	Pristine	210 ± 17.8	6	
		CNT forest	338 ± 96.2	3	61%
T700/M21	I	Pristine	331 ± 19.2	5	
		CNT forest	435 ± 12.0	2	31%
T700/M21	II	Pristine	443 ± 283	4	
		CNT forest	1155 ± 479	5	161%